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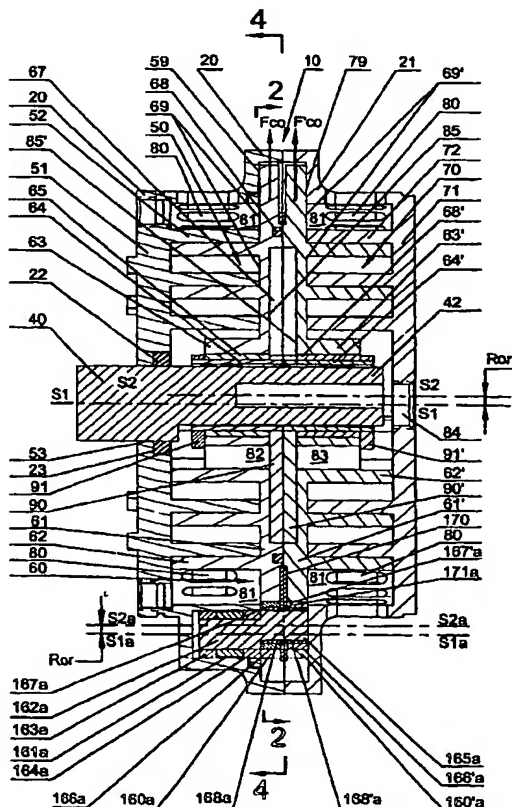
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(54) Title: **SCROLL TYPE FLUID DISPLACEMENT APPARATUS WITH FULLY COMPLIANT FLOATING SCROLLS**



(57) Abstract: The invention includes a "floating scroll" mechanism for scroll type fluid displacement apparatus (10). The dual orbiting scroll (60) has spiral vanes (62, 62') on both sides of the end plate (61, 61'). In a floating scroll, the orbiting scroll is dynamically well balanced, axially and radially. The scrolls are fully or semi- axially and radially compliant for maintaining minimum contacting forces between components, hence achieving good sealing for high speed, high efficiency, low friction wear and power loss. A crank shaft-sliding knuckle (64, 64') and/or peripheral crank handles-sliding knuckle mechanism (168a, 168'a) provide the dual orbiting scroll with radial compliant capability. A synchronizer (170) is used to synchronize the orientation of the crank handles (162a, 162b, 162c) to avoid the mechanism from jamming during operation and start up.

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SCROLL TYPE FLUID DISPLACEMENT APPARATUS WITH FULLY COMPLIANT FLOATING SCROLLS

This application is being filed as a PCT International Patent Application in the name of Scroll Laboratories, LLC, a U.S. national corporation and resident, on 5 06 March 2003, designating all countries except US, and claiming priority to U.S. Serial No. 60/371,998 filed 11 April 2002 and U.S. Serial No. 10/342,954 filed on 14 January 2003.

BACKGROUND OF THE INVENTION

This invention relates to a scroll-type positive fluid displacement apparatus 10 and more particularly to a scroll-type apparatus having a fully compliant, i.e. axially and radially compliant, floating scroll mechanism.

There is known in the art a class of devices generally referred to as "scroll" pumps, compressors and expanders, wherein two interfitting spiroidal or involute spiral elements are conjugate to each other and are mounted on separate end plates 15 forming what may be termed as fixed and orbiting scrolls. These elements are interfitted to form line contacts between spiral elements.

A pair of line contacts and the surfaces of end plates form at least one sealed off pocket. When one scroll, i.e. the orbiting scroll, makes relative orbiting motion, i.e. circular translation, with respect to the other, the line contacts on the spiral walls 20 move along the walls and thus changes the volume of the sealed off pocket. The volume change of the pocket will expand or compress the fluid in the pocket, depending on the direction of the orbiting motion.

An early patent to Creux (U.S. Pat. No. 801,182) describes this general type of device. Subsequent patents which have disclosed scroll compressors, expanders 25 and vacuum pumps are: U.S. Patent Nos. 6,123,529, 6,068,459, 5,961,297, 5,855,473, 5,788,470, 5,775,893, 5,755,564, 5,690,480, 5,632,611, 5,624,247, 5,616,015, 5,556,269, 5,322,426, 5,304,047, 5,247,795, 5,171,140, 5,098,265, 4,731,000, 4,677,949, 4,558,997, 3,989,422, 3,802,809, 3,600,114, 3,560,119, 3,011,694, 2,494,100, 2,475,247, 1,041,721. These prior patents provide so-called 30 "dual scroll" structure, i.e. the orbiting scroll elements extend from the opposite

sides of the end plate. The dual scroll structure causes the axial forces acting on the end plate of the orbiting scroll from the compressed fluid pressure to be substantially reduced or balanced. Hence, the need for a thrust bearing to support the orbiting scroll is eliminated and so is the corresponding friction wear and power
5 loss.

However, in the prior art, the orbiting scroll, no matter whether it is centrally driven or peripherally driven, makes orbiting motion with a fixed orbiting radius. U.S. Pat. No. 4,192,152 to Allen E. Armstrong et al. discloses a radial compliant linking means to accommodate the thermal expansion differences between the scroll
10 members and frame of the housing. This so-called "radial compliant" linking means is not a true radial compliant mechanism in the sense of being typically and commonly accepted in the industry. A typical "radial compliant mechanism" refers to a mechanism that can provide the orbiting scroll with freedom to travel radially until flank-flank contact between the orbiting scroll and the fixed scroll takes place
15 to seal off the compression or expansion pocket. When incompressible fluid is trapped in the compression pocket or debris is involved between the scrolls, the orbiting scroll can yield radially backwards from the fixed scroll to accommodate the situation.

U.S. Pat. No. 3,817,664 discloses a pivot shaft and coupling means, i.e. a
20 mechanical radial compliant mechanism, where the orbiting scroll is compliant radially through a coupling mechanism driven by a pivot shaft, which in turn is urged by a mechanical spring. This patent also discloses an axial compliant mechanism where the orbiting scrolls are urged towards the fixed scroll to achieve tip-base contact between scrolls by the pressure of the discharge fluid for better
25 radial sealing. This radial compliant mechanism is not practical due to the pivotal shaft and is not convenient for high rotation speed, such as a couple of thousand RPM (revolutions per minute) or higher.

In oil-free and large horsepower applications, due to the severe working conditions for the former and heavy load for the later, both call for stronger
30 anti-rotation and coupling mechanisms than an Oldham ring mechanism, which is

currently widely used in air conditioning and oil flooded scroll applications. The peripheral crank handles, as taught in U.S. Pat. No. 3,802,809, provide a strong and reliable anti-rotation and coupling mechanism. However, it restricts the orbiting scroll from radial compliance, thus sacrificing the tangential sealing between the fluid pockets formed between orbiting and fixed scrolls.

SUMMARY OF THE INVENTION

To overcome the shortcomings of conventional scroll-type fluid displacement apparatus, the present invention provides a "floating scroll" mechanism for scroll type fluid displacement apparatus. The dual orbiting scroll has spiral vanes on both sides of the end plate. In a floating scroll, the orbiting scroll is dynamically well balanced, axially and radially. The scrolls are fully or semi- axially and radially compliant for maintaining minimum contacting forces between components, hence achieving good sealing for high speed, high efficiency, low friction wear and power loss. A crank shaft-sliding knuckle and/or peripheral crank handles-sliding knuckle mechanism provide the dual orbiting scroll with radial compliant capability. A synchronizer is used to synchronize the orientation of the crank handles to prevent the mechanism from jamming during operation and start up. The scroll can be single stage or multi-stage, depending on the compression ratio, working media and other factors of the applications.

An object of the invention is to provide an improved scroll-type positive fluid displacement apparatus, which uses peripheral multiple crank handles to assure the circular translation, i.e. orbiting motion, of the orbiting scroll relative to the fixed scroll. At the same time, the scroll-type apparatus provides the orbiting scroll with the freedom to adjust its orbiting radius compliant to the fixed scroll spiral element by synchronizing the peripheral crank handles to eliminate possible mechanical jam of the handles.

It is another object of this invention to provide an improved scroll-type apparatus in which the orbiting scroll has spiral elements extending from the opposite sides of the end plate, a so called "Dual Orbiting Scroll". Both sides of

the dual orbiting scroll are dynamically similar or identical, i.e. the axial forces acting on both sides of the dual orbiting scroll are balanced or its difference is minimized. An axial compliant mechanism, by pressurizing a plenum, urges one scroll member towards the other scroll member with a controlled axial force that is just enough to overcome the opposite forces to maintain very light tip-base contact and thus, to achieve the radial sealing. The orbiting scroll with axial and radial compliant mechanisms is "floating" in the sense of force balance. The floating scroll technology allows the scroll apparatus to operate at higher rotating speeds to achieve higher fluid displacement capacity with a relatively small size and weight of the apparatus. This results in a reduced friction, reduced wear, highly efficient, compact and light scroll-type fluid displacement apparatus.

Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is a cross-sectional view of a fully compliant floating scroll compressor in accordance with this invention;

Fig. 2 is a traverse sectional view of the orbiting scroll member with a radial compliant mechanism of the present invention of Fig. 1 taken along line 2-2;

Fig. 3 is an amplified view of a peripheral crank handle, crank handle knuckle and synchronizer ring taken along line 3-3 of Fig. 2;

Fig. 4 is a traverse sectional view of Fig. 1 taken along line 4-4, illustrating the synchronizer, balancer and plenum of the present invention;

Fig. 5 is a drawing of the synchronizer ring with synchronizer bearings;

Fig. 6 is an amplified view of the driving mechanism of the central portion taken along line 6-6 of Fig. 2;

Fig. 7 is a traverse sectional view of the driving mechanism of Fig. 6 along line 7-7;

Fig. 8 is a traverse sectional view of the peripheral crank handle mechanism of Fig. 3 along line 8-8;

5 Fig. 9 is a cross-sectional view of a second embodiment of a synchronizer, timing belt and peripheral crank pulleys;

Fig. 10 is a traverse sectional view of the second embodiment of the synchronizer of the floating scroll compressor taken from Fig. 9 along line 10-10;

10 Fig. 11 is a cross-sectional view showing a floating scroll compressor with an Oldham ring as the coupling and anti-rotation mechanism;

Fig. 12 is another traverse sectional view showing a floating scroll compressor with an Oldham ring as the coupling and anti-rotation mechanism taken from Fig. 11 along line 12-12.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to Fig. 1, a scroll-type air compressor designed in accordance with the present invention is shown. The compressor unit 10 includes a front housing 20 and a rear housing 21. A main shaft 40 rotates along its axis S1-S1 when supported and driven by an external means (not shown). A drive pin 42 extrudes
20 from the front end of main shaft 40, and the central axis of drive pin 42, S2-S2, is offset from the main shaft axis, S1-S1, by a distance equal to the orbiting radius R_{or} of the orbiting scroll member 60. The orbiting radius is the radius of the orbiting circle, which is traversed by the orbiting scroll member 60 as it orbits relative to the first fixed scroll member 50 and the second fixed scroll member 70.

25 The first fixed scroll member 50 (also called front fixed scroll) has an end plate 51 from which a scroll element 52 extends. There is a hole 53 in the center of the end plate 51 to allow the main shaft 40 to pass through to drive the orbiting scroll 60.

The orbiting scroll member 60 includes circular end plates 61 and 61',
30 scroll elements 62 and 62' affixed to and extending from opposite sides of the end

plates 61 and 61', respectively, and orbiting bearing hubs 63 and 63' affixed to and extending in the central portion of the end plates 61 and 61', respectively. For convenience, the part that includes end plate 61, element 62 and hub 63 is designated as the front orbiting scroll, and end plate 61', element 62' and hub 63' as the rear orbiting scroll. Orbiting scroll 60, containing front and rear orbiting scrolls arranged back to back, is called dual scroll. The front and rear orbiting scrolls of the dual scroll orbit together and can make radial movement relative to each other during operation.

The second fixed scroll member 70 (also called rear fixed scroll) has an end plate 71, from the front side of which a scroll element 72 extends.

Scroll elements 52 and 62, 62' and 72 are interfitted at an 180 degree angular offset, and at a radial offset having an orbiting radius R_{or} , respectively. At least one sealed off fluid pocket is thereby defined between scroll elements 52 and 62, and end plates 51 and 61. And the same is true between scroll elements 62' and 72, and end plates 61' and 71.

The working fluid enters the compressor 10 from the inlet port 80 and then enters the inlet air passage 81. The inlet air passage 81 is formed between the front housing 20, the rear housing 21 and the scrolls as shown in Fig. 1. The working fluid is then sucked into the compression pockets formed between the scrolls and is compressed during the orbiting motion of the scrolls, and finally, discharges through passage 82, 83 and discharge port 84 at the central portion of the end plate 71 of the rear fixed scroll. A shaft seal 22 is located in the seal recess 23 in the first end plate 51 to seal off the discharge gas in the passage 82 from the ambient.

Referring to Figs. 1-5, the driving, anti-rotation and radial compliant mechanisms are explained. The drive pin 42 of the main shaft 40 drives the orbiting scroll 60 via central driving knuckles 64 and 64' and driving pin bearing 65 and 65', respectively. At the periphery of the orbiting scroll 60, there are three pairs of equally spaced peripheral extensions 160a, 160b and 160c from end plate 61 and 160'a, 160'b and 160'c from end plate 61', respectively as shown in Fig. 1 and 2. For simplicity, only the functions for extension 160a and 160'a, and the relevant

parts, are described. The rest function in a similar and are not separately described.

Referring to Fig. 1, 2 and 3, there are three bearing holes 161a, 161b and 161c in the front housing 20 (only 161a shown). The crank handle 162a is rotatably supported by two bearings 163a and 164a. Crank handle pin 165a
5 extrudes from crank handle 162a. The centerline S1a of the crank handle 162a and centerline S2a of the crank handle pin 165a are offset at a distance corresponding to the orbiting radius Ror.

Extensions 160a and 160'a of the orbiting scroll 60 have bearing holes 166a and 166'a where crank handle bearings 167a and 167'a are located, respectively.
10 Peripheral crank handle 162a through crank handle pin 165a, peripheral crank knuckles 168a and 168'a, and handle bearings 167a and 167'a together with the other two pairs of peripheral handles 162b and 162c, and their corresponding parts keep the orbiting scroll 60 in orbiting motion and prevent it from rotation.

Referring to Fig. 7, there is a slot 190 in the front driving knuckle 64. The
15 driving pin 42 is located in slot 190. The slot 190 is longer radially than the driving pin 42. When the driving pin 42 rotates counter-clockwise as shown by arrow B, the driving surface 191 of the driving pin 42 pushes the sliding surface 192 of the front driving knuckle 64. The driving knuckle 64 can move radially, as shown by arrow C. The above description is also true for the rear driving knuckle
20 64' and relevant parts.

Referring to Figs. 1, 7 and 8, when shaft 40 rotates, the front and rear orbiting scrolls of orbiting scroll 60 are exerted upon by centrifugal forces F_{co} and F'_{co} , respectively, generated by their own orbiting motion. In addition to the orbiting motion, the front and rear orbiting scrolls of the orbiting scroll 60 slide
25 radially together with the driving knuckle 64 and 64' and the peripheral knuckles 168a, 168'a, 168b, 168'b, 168c and 168'c under the action of the centrifugal forces until the orbiting scrolls stop by flank-flank contacting their corresponding fixed scrolls. As a result, this is radial-compliant.

Using a sliding knuckle-crank shaft mechanism to achieve radial compliance
30 is well known in the art. However, due to technical difficulties this mechanism has

not been adapted for a dual scroll design as reviewed in the background introduction above. The difficulty is to synchronize the orientation of the peripheral crank handles, such that the orbiting scroll can slide freely in the radial direction without jamming. The invention provides a mechanism, including peripheral crank handles, sliding knuckles and a crank handle synchronizer, which makes the orbiting scroll radial compliant. Referring to Figs. 1-5 the function of the synchronizer 170 is explained. In Fig. 4, S1a-S2a, S1b-S2b and S1c-S2c are the lines connecting the centers of crank handles 162a, 162b and 162c with the centers of the crank handle pins 165a, 165b and 165c, respectively. The lines S1a-S2a, S1b-S2b and S1c-S2c must remain parallel to each other, i.e. synchronized, all the time no matter whether the scroll apparatus is in operation or at rest. Otherwise, the crank handles 162a, 162b and 162c, and the driving shaft 40, and in turn the orbiting scroll 60, could be jammed at start up or during operation due to the freedom of motion of each knuckle in its radial and tangential directions.

In order to maintain the synchronization of the crank handles, synchronizer 170, as shown in Figs. 1-5, is connected to the crank handle pins 165a, 165b and 165c via synchronizer bearings 171a, 171b and 171c, respectively. The synchronizer 170 makes circular translation, i.e. orbiting motion similar to the orbiting scrolls, and keeps the three crank handle pins in a triangular relation, i.e. being synchronized, such that the lines S1a-S2a, S1b-S2b and S1c-S2c remain parallel to each other all the time.

Returning now to the orbiting scroll 60, which is acted on by the centrifugal force F_{co} and F'_{co} , and referring to Figs. 1 and 4, the centrifugal forces F_{co} and F'_{co} are partially balanced by that of counterweights 90 and 91, and 90' and 91', respectively, such that the resulting net centrifugal forces are just enough to overcome the radial separating forces caused by the compressed gas. During operation, because the lines S1a-S2a, S1b-S2b and S1c-S2c are synchronized, the orbiting scroll 60 will move along the radial direction, i.e. parallel to lines S1a-S2a, S1b-S2b and S1c-S2c, by the net centrifugal forces until the flanks of orbiting scroll elements 62 and 62' very lightly contact the flanks of the fixed scroll elements 52

and 72, respectively, to achieve tangential sealing between the compression pockets. Overall balance of centrifugal forces of the scroll apparatus is achieved by other counterweights in a traditional way, and is not discussed here.

Referring to Figs. 1 and 4, the axial compliant mechanism for the dual scroll structure will be described. The orbiting scroll 60 includes front end plate 61 and rear end plate 61'. There is a plenum chamber 67 formed between the two end plates. Sealing element 68 seals off plenum chamber 67 from air passage 81 and suction ambient. At start up, the elasticity of the sealing element 68 urges both front and rear orbiting scrolls towards their corresponding mating fixed scrolls to achieve light tip-base contact between the mating scrolls. The plenum chamber 67 is connected to the discharge air through passage 82 and 83. The areas of the surfaces 85 and 85' are so designed that the forces of the discharge air acting on them slightly exceed the total axial forces, respectively acting on the opposite surfaces 69 and 69' of the end plates 61 and 61', and the tips of the scroll elements 62 and 62' of the front and rear orbiting scrolls by the compressed air. The net axial forces will urge the front and rear orbiting scrolls, respectively, towards the corresponding mating fixed scrolls to achieve very light contact at six pairs of contacting surfaces. Among them, two pairs of contacting surfaces are between the tip surfaces of two orbiting scrolls against the mating base surfaces of the end plates of corresponding fixed scrolls. Two other pairs of contacting surfaces are between the tip surfaces of two fixed scrolls against the mating base surfaces of the end plates of corresponding orbiting scrolls. The remaining two pairs of contacting surfaces are the anti-thrust surfaces 59 and 79 of the front and rear housings 20 and 21 against the thrust surfaces 69 and 69' of the front and rear orbiting scrolls, respectively. The anti-thrust surfaces 59 and 79 support the surfaces 69 and 69' of the orbiting scroll, respectively, to avoid possible tipping motion of the orbiting scrolls. The surface contact between the mating surfaces of the above-mentioned six pairs of contacting surfaces is not necessarily taking place at the same time when assembled. Nevertheless, after wearing-in, light contact between the six pairs of surfaces will take place. This axial compliant mechanism enables a good radial

sealing between compression pockets and makes the wear between the orbiting and fixed scrolls negligible and self-compensating. Many axial compliant schemes have been taught in the prior art, and some of them might be adapted for use with this invention.

5 Figs. 9 and 10 illustrate another embodiment of the synchronizer for a radial compliant mechanism with a dual scroll structure. In these figures, elements corresponding to elements in Figures 1-8 are referenced by the same reference numerals.

In this embodiment there are three peripheral crank timing pulleys, 173a, 173b and 173c, firmly attached to the crank handles 162a, 162b and 162c, respectively. A timing belt 174 links the three timing pulleys, 173a, 173b and 173c and synchronizes them such that the lines S1a-S2a, S1b-S2b and S1c-S2c, that connect the centers of the crank handles, 162a, 162b and 162c with the centers of the crank handle pins 165a, 165b and 165c, respectively, remain parallel to each other all the time no matter whether the scroll apparatus is in operation or is stationary. Idle wheels 175 keep the timing belt 174 in position and maintain proper tension for smooth running.

There are many mechanisms, e.g. gear systems, etc., that could alternatively be used as a synchronizer as long as they can keep the lines S1a-S2a, S1b-S2b and S1c-S2c parallel to each other all the time no matter whether the scroll apparatus is in operation or is stationary.

Figs. 11 and 12 illustrate still another embodiment of a radial compliant mechanism for a floating scroll apparatus where an Oldham ring mechanism is used as the coupling and rotation-prevention mechanism instead of the peripheral crank handle mechanism discussed above. In this embodiment, elements corresponding to elements in Figures 1-10 are referenced by the same reference numerals

When shaft 40 rotates, the crank pin 42 drives the orbiting scroll 60 via driving knuckles 64 and 64', and driving bearings 65 and 65' to make counterclockwise circular translation, i.e. orbiting motion. Oldham ring 176 guides the orbiting motion of the orbiting scroll member 60. The work principle of the

Oldham ring is well known in the art and further explanation is not necessary. A key point of this embodiment is to allow the front and rear orbiting scrolls to make independent radial travel under the influence of the centrifugal forces. Thus, the radial flank-flank contacts between the mating fixed and orbiting scrolls can be
5 achieved.

While the above-described embodiments of the invention are preferred, those skilled in this art will recognize modifications of structure, arrangement, composition and the like which do not part from the true scope of the invention. The invention is defined by the appended claims, and all devices and/or methods
10 that come within the meaning of the claims, either literally or by equivalents, are intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A positive fluid displacement apparatus, comprising:
 - a) an orbiting scroll member including an end plate having two involute wraps affixed to opposite surfaces of said end plate and three, equally-spaced peripheral extensions;
 - b) first and second oppositely disposed, fixed scroll members, each fixed scroll member including an end plate having an involute wrap affixed to an internal facing surface of the respective plate, each involute wrap of the fixed scroll members engageable respectively with one involute wrap of said orbiting scroll member, wherein when said orbiting scroll member orbits with respect to said fixed scroll members, flanks of said engaged wraps of the orbiting and fixed scroll members along with the end plate of said orbiting scroll member and the internal facing surfaces of said end plates of said fixed scroll members define moving pockets of variable volume and zones of high and low fluid pressures;
 - c) a housing supporting said first and second fixed scroll members;
 - d) a rotatable shaft within said housing arranged to drive said orbiting scroll member in orbiting motion with respect to said fixed scroll members;
 - e) three equally spaced crank handles, each rotatably supported by said housing;
 - f) radially compliant linking means connecting said shaft to said orbiting scroll member and connecting said crank handles to said peripheral extensions of said orbiting scroll member to maintain a predetermined angular relationship between said orbiting and fixed scroll members and to allow said orbiting scroll member to slide radially to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.

2. A positive fluid displacement apparatus in accordance with claim 1, wherein said end plate of said orbiting scroll member comprises a front plate and a rear plate arranged back to back; said two involute wraps of said orbiting scroll member are affixed to and extend from opposite sides of the front and rear plates, respectively; and said orbiting scroll member comprises a front orbiting scroll member that includes said front plate and said attached involute wrap, and a rear orbiting scroll member that includes said rear plate and said attached involute wrap.

3. A positive fluid displacement apparatus in accordance with claim 2, wherein said front orbiting scroll member and said rear orbiting scroll member are able to slide radially with respect to each other while orbiting.

4. A positive fluid displacement apparatus in accordance with claim 3, wherein:

- a) said shaft has a crank pin extending from an end thereof;
- b) a front bearing hub and a rear bearing hub are attached to a central portion of said front and rear plates, respectively, of said orbiting scroll member; and
- c) said radially compliant linking means having front and rear drive knuckles that are rotatable within said front and rear bearing hubs of said orbiting scroll member, said knuckles are driven by and rotate together with said crank pin and are able to slide radially together with said front and rear bearing hubs, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.

5. A positive fluid displacement apparatus in accordance with claim 4, wherein:
- a) each of said crank handles has a crank handle pin affixed to and extending from an end thereof; and
 - b) said radially compliant linking means further includes three pairs of crank handle knuckles that are rotatable within said three peripheral extensions, respectively, of said orbiting scroll member, and are driven by and rotate together with said crank handle pins, and said crank handle knuckles are able to slide radially together with said peripheral extensions, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven and to maintain a predetermined angular relationship between said orbiting and fixed scroll members.
6. A positive fluid displacement apparatus in accordance with claim 4, wherein at least one counterbalancer is attached to each of said front and rear drive knuckles to balance part of the centrifugal forces acting on said front and rear orbiting scroll members such that a radial separating force caused by displaced gas is overcome to maintain light contact between the involute wraps of said orbiting and fixed scroll members.
7. A positive fluid displacement apparatus in accordance with claim 5, wherein at least one counterbalancer is attached to each of said three crank handle knuckles engaged with said extensions, such that a part of the centrifugal force acting on said front and rear orbiting scroll members is balanced and a radial separating force caused by displaced gas is overcome to maintain light sealing contact between the involute wraps of said orbiting and fixed scroll members.

8. A positive fluid displacement apparatus, comprising:
- a) an orbiting scroll member including an end plate having two involute wraps affixed to opposite surfaces of said end plate and three, equally-spaced peripheral extensions;
 - b) first and second oppositely disposed, fixed scroll members, each fixed scroll member including an end plate having an involute wrap affixed to an internal facing surface of the respective plate, each involute wrap of the fixed scroll members engageable respectively with one involute wrap of said orbiting scroll member, wherein when said orbiting scroll member orbits with respect to said fixed scroll members, flanks of said engaged wraps of the orbiting and fixed scroll members along with said end plate of said orbiting scroll member and the internal facing surfaces of said end plates of said fixed scroll members define moving pockets of variable volume and zones of high and low fluid pressures;
 - c) a housing supporting said first and second fixed scroll members;
 - d) a rotatable shaft within said housing arranged to drive said orbiting scroll member in orbiting motion with respect to said fixed scroll members;
 - e) three equally spaced crank handles, each rotatably supported by said housing;
 - f) radially compliant linking means connecting said shaft to said orbiting scroll member and connecting said crank handles to said peripheral extensions of said orbiting scroll member to maintain a predetermined angular relationship between said orbiting and fixed scroll members and to allow said orbiting scroll member to slide radially to effect tangential sealing between said involute wraps of said orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven;
 - g) a synchronizer synchronizing said crank handles such that in a plane perpendicular to said rotatable shaft, lines drawn through centers of

said crank handles and perpendicular to the direction of orbiting motion of said orbiting scroll member remain parallel.

9. A positive fluid displacement apparatus in accordance with claim 8, wherein said synchronizer has a ring with three, equally-spaced peripheral extensions connected to said crank handles, and said synchronizer orbits together with said orbiting scroll member.

10. A positive fluid displacement apparatus in accordance with claim 9, wherein said end plate of said orbiting scroll member comprises a front plate and a rear plate arranged back to back; said two involute wraps of said orbiting scroll member are affixed to and extend from opposite sides of the front and rear plates, respectively; and said orbiting scroll member comprises a front orbiting scroll member that includes said front plate and said attached involute wrap, and a rear orbiting scroll member that includes said rear plate and said attached involute wrap.

11. A positive fluid displacement apparatus in accordance with claim 10, wherein said front orbiting scroll member and said rear orbiting scroll member are able to slide radially with respect to each other while orbiting.

12. A positive fluid displacement apparatus in accordance with claim 11, wherein:

- a) said shaft has a crank pin extending from an end thereof;
- b) a front bearing hub and a rear bearing hub are attached to a central portion of said front and rear plates, respectively, of said orbiting scroll member; and
- c) said radially compliant linking means having front and rear drive knuckles that are rotatable within said front and rear bearing hubs of said orbiting scroll member, said knuckles are driven by and rotate together with said crank pin and are able to slide radially together with

said front and rear bearing hubs, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.

13. A positive fluid displacement apparatus in accordance with claim 12, wherein:
- a) each of said crank handles has a crank handle pin affixed to and extending from an end thereof; and
 - b) said radially compliant linking means further includes three pairs of crank handle knuckles that are rotatable within said three peripheral extensions, respectively, of said orbiting scroll member, and are driven by and rotate together with said crank handle pins, and said crank handle knuckles are able to slide radially together with said peripheral extensions, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven and to maintain a predetermined angular relationship between said orbiting and fixed scroll members.
14. A positive fluid displacement apparatus in accordance with claim 12, wherein at least one counterbalancer is attached to each of said front and rear drive knuckles to balance part of the centrifugal forces acting on said front and rear orbiting scroll members such that a radial separating force caused by displaced gas is overcome to maintain light contact between the involute wraps of said orbiting and fixed scrolls.
15. A positive fluid displacement apparatus in accordance with claim 13, wherein at least one counterbalancer is attached to each of said three crank handle knuckles engaged with said extensions, such that a part of the centrifugal force

acting on said front and rear orbiting scroll members is balanced and a radial separating force caused by displaced gas is overcome to maintain light sealing contact between the involute wraps of said orbiting and fixed scroll members.

16. A positive fluid displacement apparatus, comprising:
 - a) an orbiting scroll member including an end plate having a front plate and a rear plate arranged back to back, and two involute wraps are affixed to and extend from opposite sides of the front and rear plates, respectively; said orbiting scroll member comprises a front orbiting scroll member that includes said front plate and said attached involute wrap, and a rear orbiting scroll member that includes said rear plate and said attached involute wrap; and three, equally-spaced peripheral extensions for each of said front and rear plates;
 - b) first and second oppositely disposed, fixed scroll members, each fixed scroll member including an end plate having an involute wrap affixed to an internal facing surface of the respective plate, each involute wrap of the fixed scroll members engageable respectively with one involute wrap of said orbiting scroll member, wherein when said orbiting scroll member orbits with respect to said fixed scroll members, flanks of said engaged wraps of the orbiting and fixed scroll members along with said front and rear plates of said orbiting scroll member and the internal facing surfaces of said end plates of said fixed scroll members define moving pockets of variable volume and zones of high and low fluid pressures;
 - c) a housing supporting said first and second fixed scroll members;
 - d) a rotatable shaft within said housing arranged to drive said orbiting scroll member in orbiting motion with respect to said fixed scroll members;
 - e) three equally spaced crank handles, each rotatably supported by said housing;

- f) radially compliant linking means connecting said shaft to said orbiting scroll member and connecting said crank handles to said peripheral extensions of said orbiting scroll member to maintain a predetermined angular relationship between said orbiting and fixed scroll members and to allow said orbiting scroll member to slide radially to effect tangential sealing between said involute wraps of said orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven;
- g) a synchronizer synchronizing said crank handles such that in a plane perpendicular to said rotatable shaft, lines drawn through centers of said crank handles and perpendicular to the direction of orbiting motion of said orbiting scroll member remain parallel; and
- h) a plenum chamber formed between said front and rear plates of said front and rear orbiting scroll members, wherein a pressurized fluid introduced into said plenum chamber urges the front and rear orbiting scroll members towards the fixed scroll members.

17. A positive fluid displacement apparatus in accordance with claim 16, wherein said synchronizer has a ring with three, equally-spaced peripheral extensions connected to said crank handles, and said synchronizer orbits together with said orbiting scroll member.

18. A positive fluid displacement apparatus in accordance with claim 17, wherein said front orbiting scroll member and said rear orbiting scroll member are able to slide radially with respect to each other while orbiting.

19. A positive fluid displacement apparatus in accordance with claim 18, wherein a sealing element made of resilient material is located between said front and rear plates of said front and rear orbiting scroll members to seal off said plenum chamber such that a pressurized fluid introduced into the plenum chamber is sealed

off from neighboring areas containing fluid at different pressure inside said housing.

20. A positive fluid displacement apparatus in accordance with claim 19, wherein:
- a) said shaft has a crank pin extending from an end thereof;
 - b) a front bearing hub and a rear bearing hub are attached to a central portion of said front and rear plates, respectively, of said orbiting scroll member; and
 - c) said radially compliant linking means having front and rear drive knuckles that are rotatable within said front and rear bearing hubs of said orbiting scroll member, said knuckles are driven by and rotate together with said crank pin and are able to slide radially together with said front and rear bearing hubs, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.
21. A positive fluid displacement apparatus in accordance with claim 20, wherein:
- a) each of said crank handles has a crank handle pin affixed to and extending from an end thereof; and
 - b) said radially compliant linking means further includes three pairs of crank handle knuckles that are rotatable within said three peripheral extensions, respectively, of said orbiting scroll member, and are driven by and rotate together with said crank handle pins, and said crank handle knuckles are able to slide radially together with said peripheral extensions, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven and to

maintain a predetermined angular relationship between said orbiting and fixed scroll members.

22. A positive fluid displacement apparatus in accordance with claim 20, wherein at least one counterbalancer is attached to each of said front and rear drive knuckles to balance part of the centrifugal forces acting on said front and rear orbiting scroll members such that a radial separating force caused by displaced gas is overcome to maintain light contact between the involute wraps of said orbiting and fixed scroll members.

23. A positive fluid displacement apparatus in accordance with claim 21, wherein at least one counterbalancer is attached to each of said three crank handle knuckles engaged with said extensions, such that a part of the centrifugal force acting on said front and rear orbiting scroll members is balanced and a radial separating force caused by displaced gas is overcome to maintain light sealing contact between the involute wraps of said orbiting and fixed scroll members.

24. A positive fluid displacement apparatus, comprising in combination
- a) an orbiting scroll member including an end plate having a front plate and a rear plate arranged back to back, and two involute wraps are affixed to and extend from opposite sides of the front and rear plates, respectively; said orbiting scroll member comprises a front orbiting scroll member that includes said front plate and said attached involute wrap, and a rear orbiting scroll member that includes said rear plate and said attached involute wrap; and three, equally-spaced peripheral extensions for each of said front and rear plates;
 - b) first and second oppositely disposed, fixed scroll members, each fixed scroll member including an end plate having an involute wrap affixed to an internal facing surface of the respective plate, each involute wrap of the fixed scroll members engageable respectively with one involute

wrap of said orbiting scroll member, wherein when said orbiting scroll member orbits with respect to said fixed scroll members, flanks of said engaged wraps of the orbiting and fixed scroll members along with said front and rear plates of said orbiting scroll member and the internal facing surfaces of said end plates of said fixed scroll members define moving pockets of variable volume and zones of high and low fluid pressures;

- c) a housing supporting said first and second fixed scroll members;
- d) a rotatable shaft within said housing arranged to drive said orbiting scroll member in orbiting motion with respect to said fixed scroll members;
- e) three equally spaced crank handles, each rotatably supported by said housing, and each having a timing belt pulley attached to it;
- f) radially compliant linking means connecting said shaft to said orbiting scroll member and connecting said crank handles to said peripheral extensions of said orbiting scroll member to maintain a predetermined angular relationship between said orbiting and fixed scroll members and to allow said orbiting scroll member to slide radially to effect tangential sealing between said involute wraps of said orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven;
- g) a plenum chamber formed between said front and rear plates of said front and rear orbiting scroll members, wherein a pressurized fluid introduced into said plenum chamber urges the front and rear orbiting scroll members towards the fixed scroll members; and
- h) a synchronizer including a timing belt and multiple idle wheels, said synchronizer synchronizing said crank handles such that in a plane perpendicular to said rotatable shaft, lines drawn through centers of said crank handles and perpendicular to the direction of orbiting motion of said orbiting scroll member remain parallel.

25. A positive fluid displacement apparatus in accordance with claim 24, wherein said front orbiting scroll member and said rear orbiting scroll member are able to slide radially with respect to each other while orbiting.

26. A positive fluid displacement apparatus in accordance with claim 25, wherein a sealing element made of resilient material is located between said front and rear plates of said front and rear orbiting scroll members to seal off said plenum chamber such that a pressurized fluid introduced into the plenum chamber is sealed off from neighboring areas containing fluid at different pressure inside said housing.

27. A positive fluid displacement apparatus in accordance with claim 26, wherein:

- a) said shaft has a crank pin extending from an end thereof;
- b) a front bearing hub and a rear bearing hub are attached to a central portion of said front and rear plates, respectively, of said orbiting scroll member; and
- c) said radially compliant linking means having front and rear drive knuckles that are rotatable within said front and rear bearing hubs of said orbiting scroll member, said knuckles are driven by and rotate together with said crank pin and are able to slide radially together with said front and rear bearing hubs, respectively, to effect tangential sealing between said involute wraps of the orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.

28. A positive fluid displacement apparatus in accordance with claim 27, wherein:

- a) each of said crank handles has a crank handle pin affixed to and extending from an end thereof; and

- b) said radially compliant linking means further includes three pairs of crank handle knuckles that are rotatable within said three peripheral extensions, respectively, of said orbiting scroll member, and are driven by and rotate together with said crank handle pins, and said crank handle knuckles are able to slide radially together with said peripheral extensions, respectively, to effect tangential sealing between said involute wraps of said orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven and to maintain a predetermined angular relationship between said orbiting and fixed scroll members.

29. A positive fluid displacement apparatus in accordance with claim 27, wherein at least one counterbalancer is attached to each of said front and rear drive knuckles to balance part of the centrifugal forces acting on said front and rear orbiting scroll members such that a radial separating force caused by displaced gas is overcome to maintain light contact between the involute wraps of said orbiting and fixed scroll members.

30. A positive fluid displacement apparatus in accordance with claim 28, wherein at least one counterbalancer is attached to each of said three crank handle knuckles engaged with said extensions, such that a part of the centrifugal force acting on said front and rear orbiting scroll members is balanced and a radial separating force caused by displaced gas is overcome to maintain light sealing contact between the involute wraps of said orbiting and fixed scroll members.

31. A positive fluid displacement apparatus, comprising:
- a) an orbiting scroll member including an end plate having a front plate and a rear plate arranged back to back, and two involute wraps are affixed to and extend from opposite sides of the front and rear plates, respectively; said orbiting scroll member comprises a front orbiting

- scroll member that includes said front plate and said attached involute wrap, and a rear orbiting scroll member that includes said rear plate and said attached involute wrap; and three, equally-spaced peripheral extensions for each of said front and rear plates;
- b) first and second oppositely disposed, fixed scroll members, each fixed scroll member including an end plate having an involute wrap affixed to an internal facing surface of the respective plate, each involute wrap of the fixed scroll members engageable respectively with one involute wrap of said orbiting scroll member, wherein when said orbiting scroll member orbits with respect to said fixed scroll members, flanks of said engaged wraps of the orbiting and fixed scroll members along with said front and rear plates of said orbiting scroll member and the internal facing surfaces of said end plates of said fixed scroll members define moving pockets of variable volume and zones of high and low fluid pressures;
 - c) a housing supporting said first and second fixed scroll members;
 - d) a rotatable shaft within said housing arranged to drive said orbiting scroll member in orbiting motion with respect to said fixed scroll members;
 - e) a plenum chamber formed between said front and rear plates of said front and rear orbiting scroll members, wherein a pressurized fluid introduced into said plenum chamber urges the front and rear orbiting scroll members towards the fixed scroll members;
 - f) an Oldham coupling having two sets of keys perpendicular to each other, each set of said keys is engaged with said orbiting scroll member and said housing, respectively, to maintain a predetermined angular relationship between said orbiting and fixed scroll members.

32. A positive fluid displacement apparatus in accordance with claim 31, wherein:

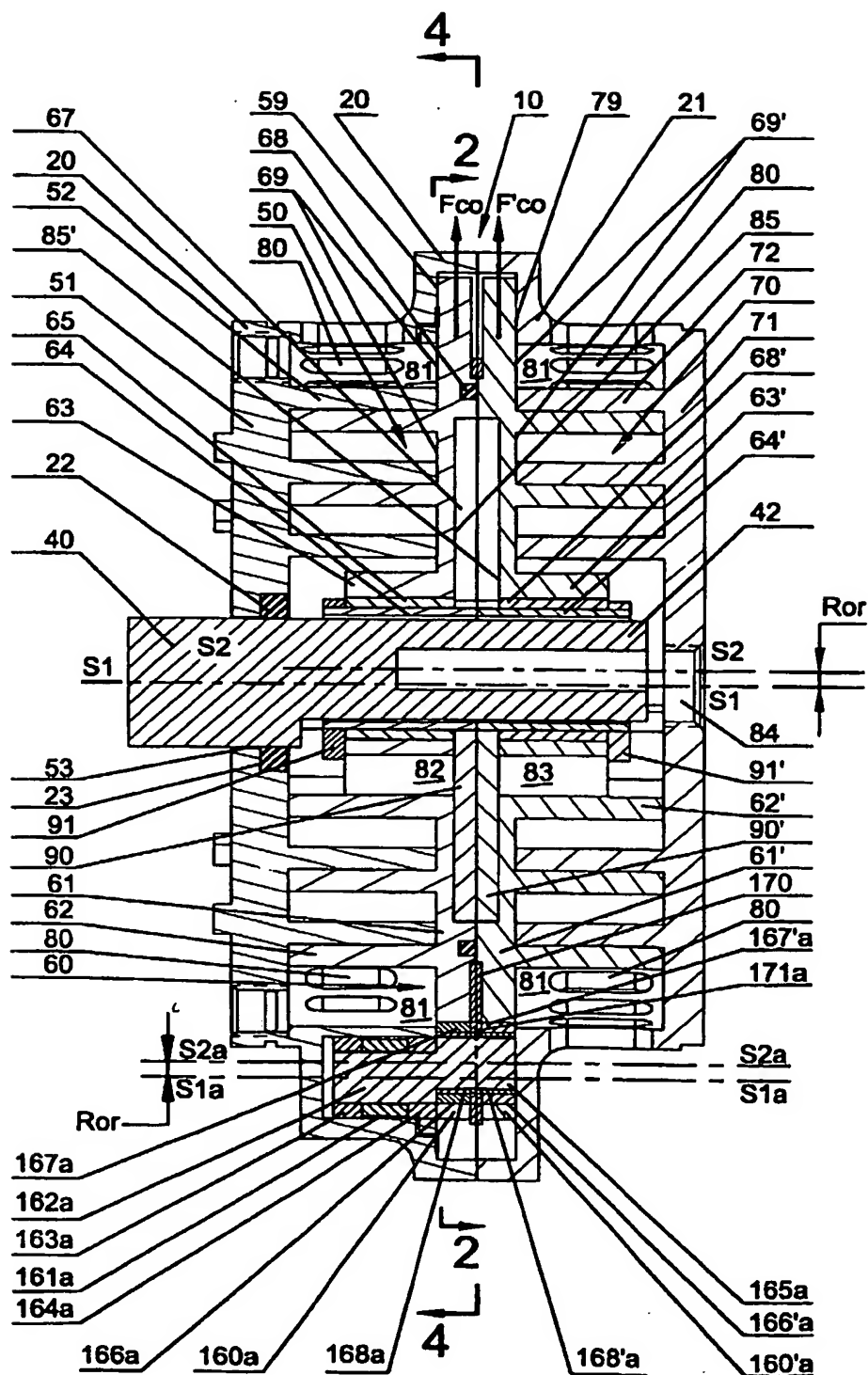
- a) said shaft has a crank pin extending from an end thereof;
- b) a front bearing hub and a rear bearing hub are attached to a central portion of said front and rear plates, respectively, of said orbiting scroll member; and
- c) a radially compliant linking means having front and rear drive knuckles that are rotatable within said front and rear bearing hubs of said orbiting scroll member, said knuckles are driven by and rotate together with said crank pin and are able to slide radially together with said front and rear bearing hubs, respectively, to effect tangential sealing between said involute wraps of said orbiting and fixed scroll members which make moving line contact as said orbiting scroll member is driven.

33. A positive fluid displacement apparatus in accordance with claim 32 wherein a sealing element made of resilient material is located between said front and rear plates of said front and rear orbiting scroll members to seal off said plenum chamber such that a pressurized fluid introduced into the plenum chamber is sealed off from neighboring areas containing fluid at different pressure inside said housing.

34. A positive fluid displacement apparatus in accordance with claim 33, wherein at least one counterbalancer is attached to each of said front and rear drive knuckles to balance part of the centrifugal forces acting on said front and rear orbiting scroll members such that a radial separating force caused by displaced gas is overcome to maintain light contact between the involute wraps of said orbiting and fixed scroll members.

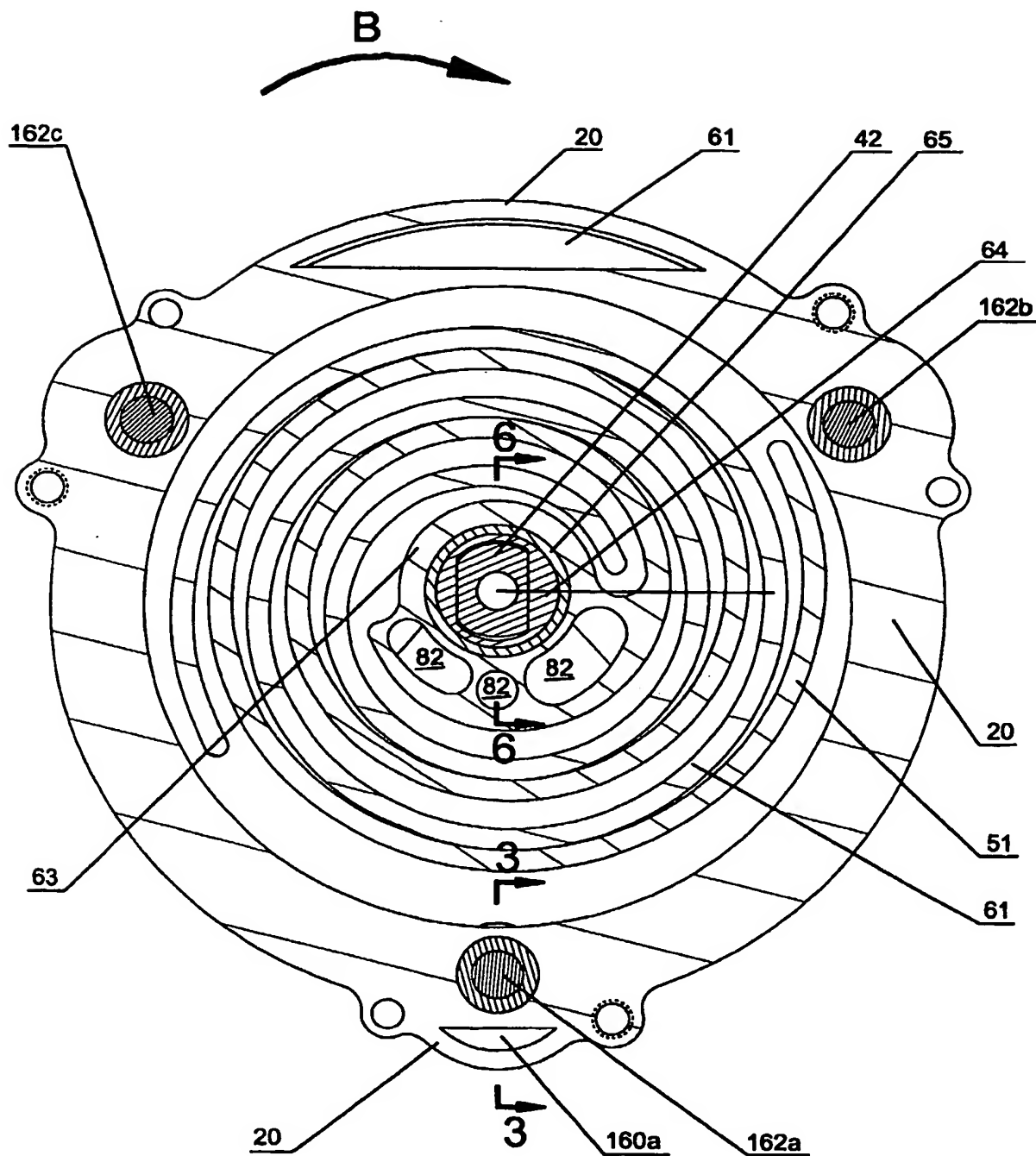
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FIG. 1



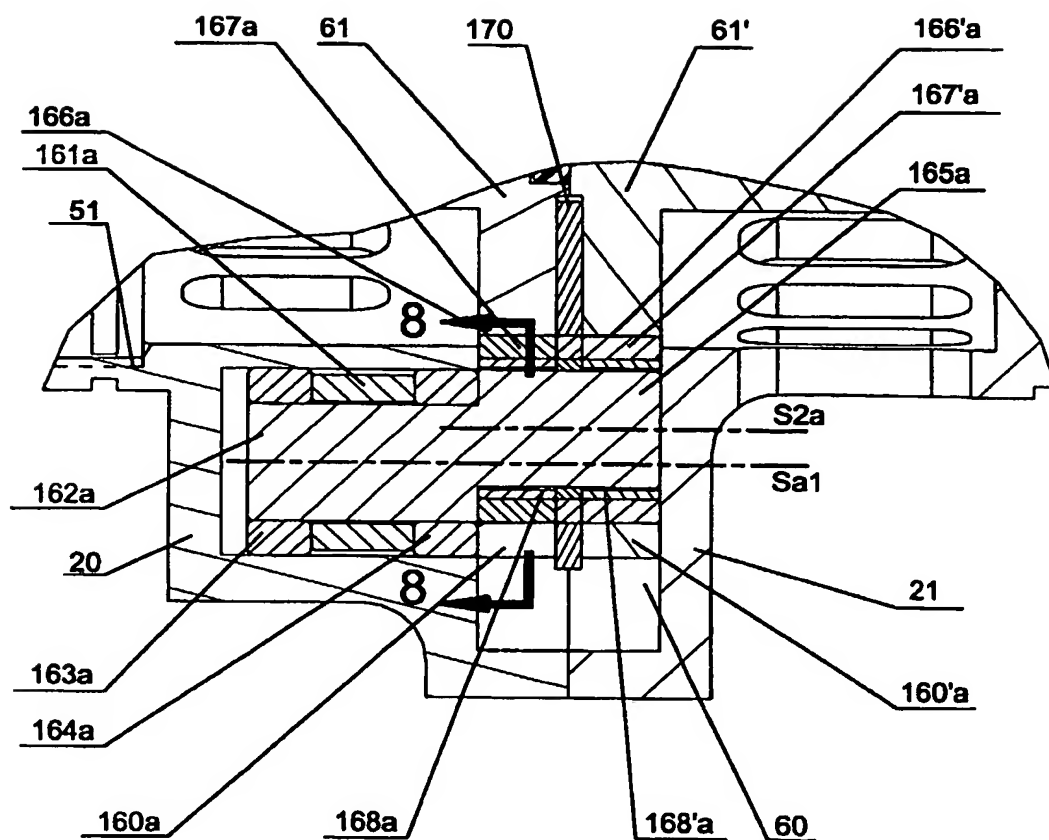
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FIG.2



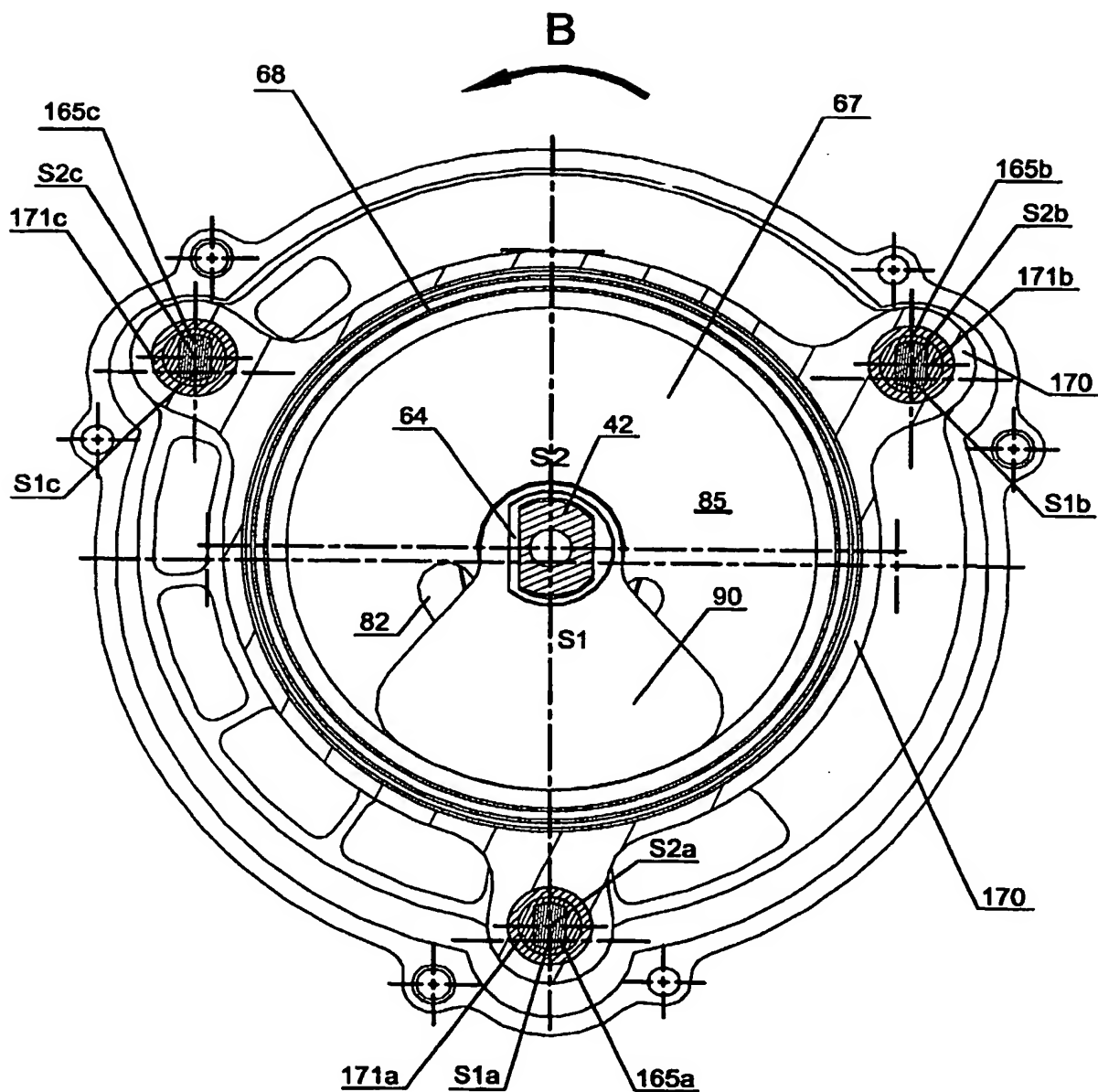
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FIG.3



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FIG. 4



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FIG.5

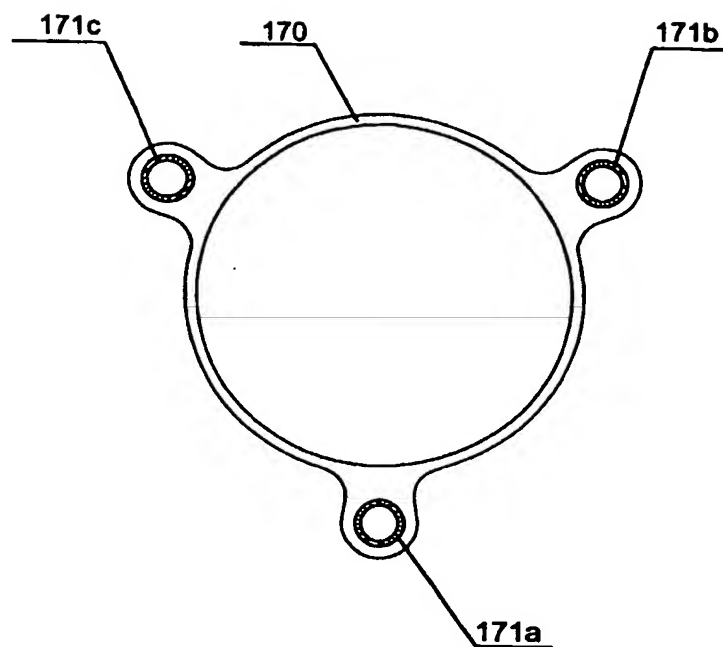
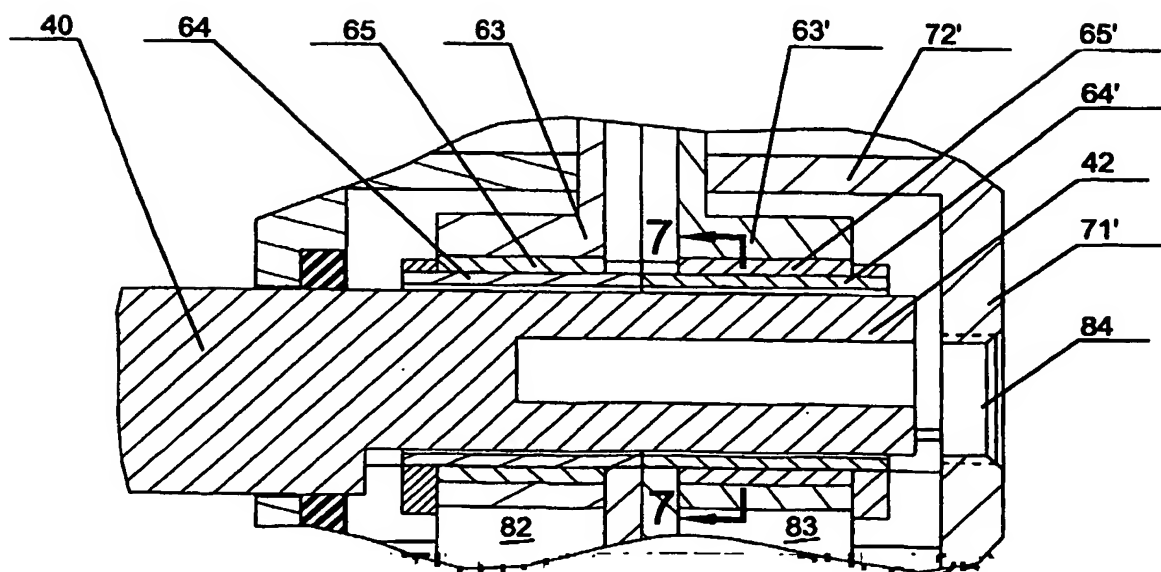


FIG.6



SUBSTITUTE SHEET (RULE 26)

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FIG.7

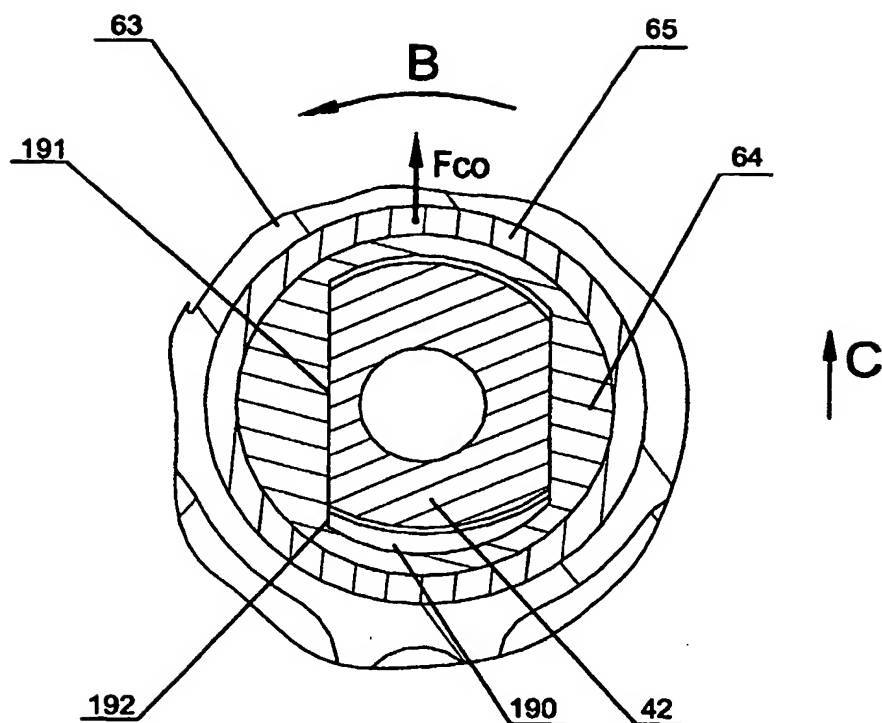
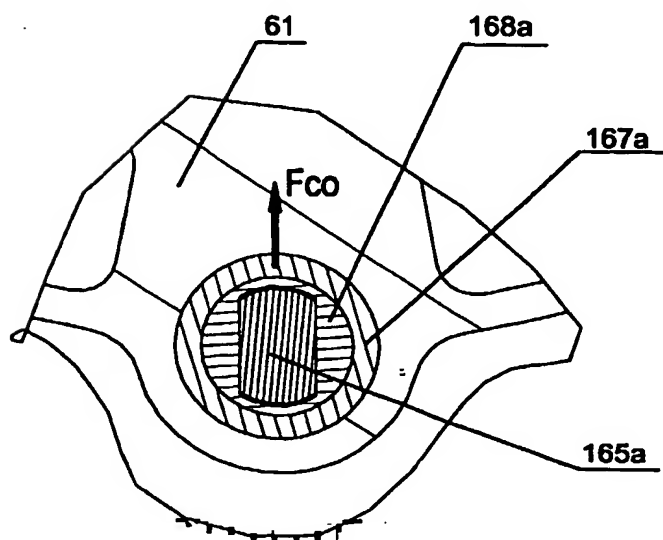
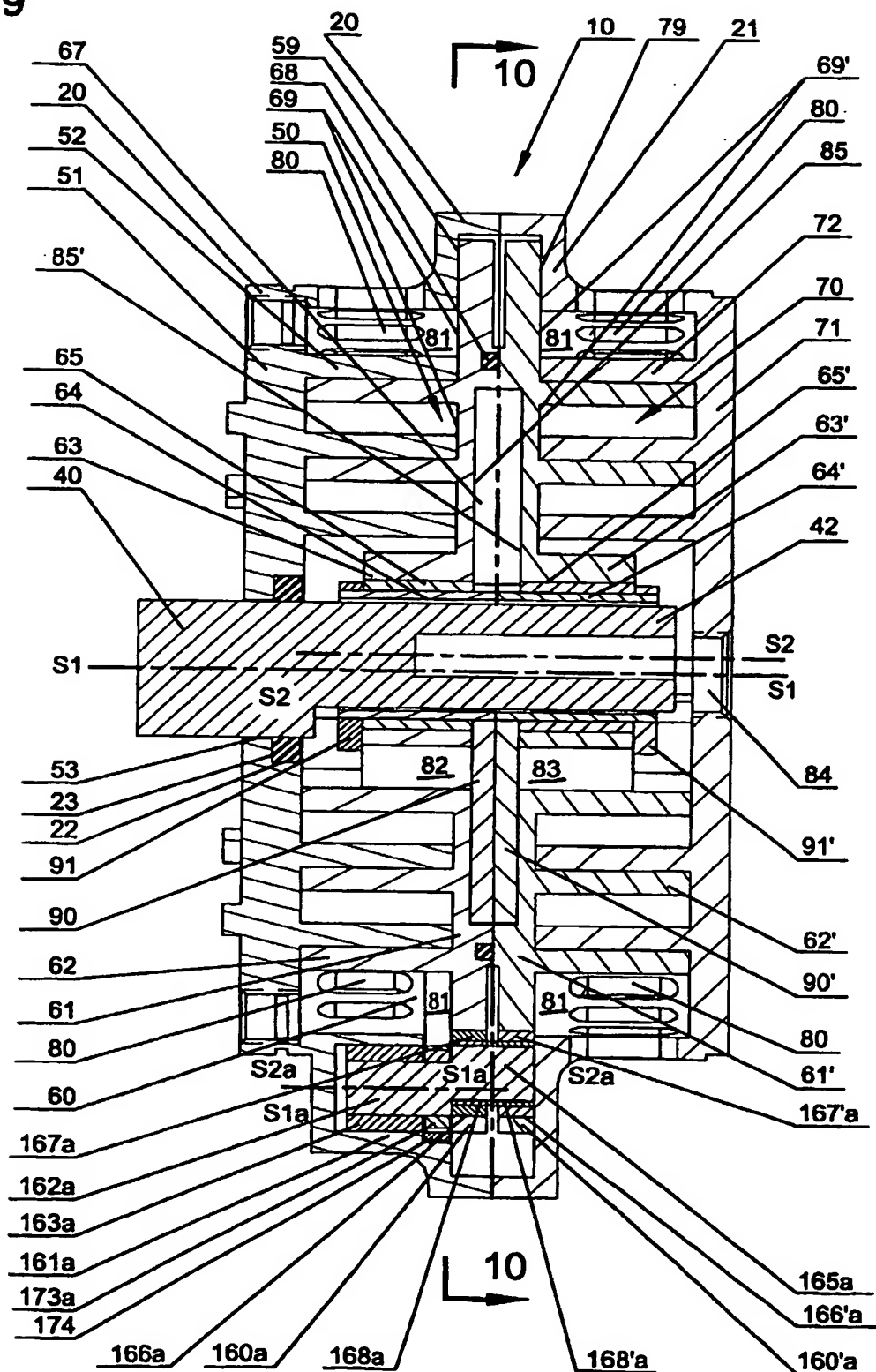


FIG.8



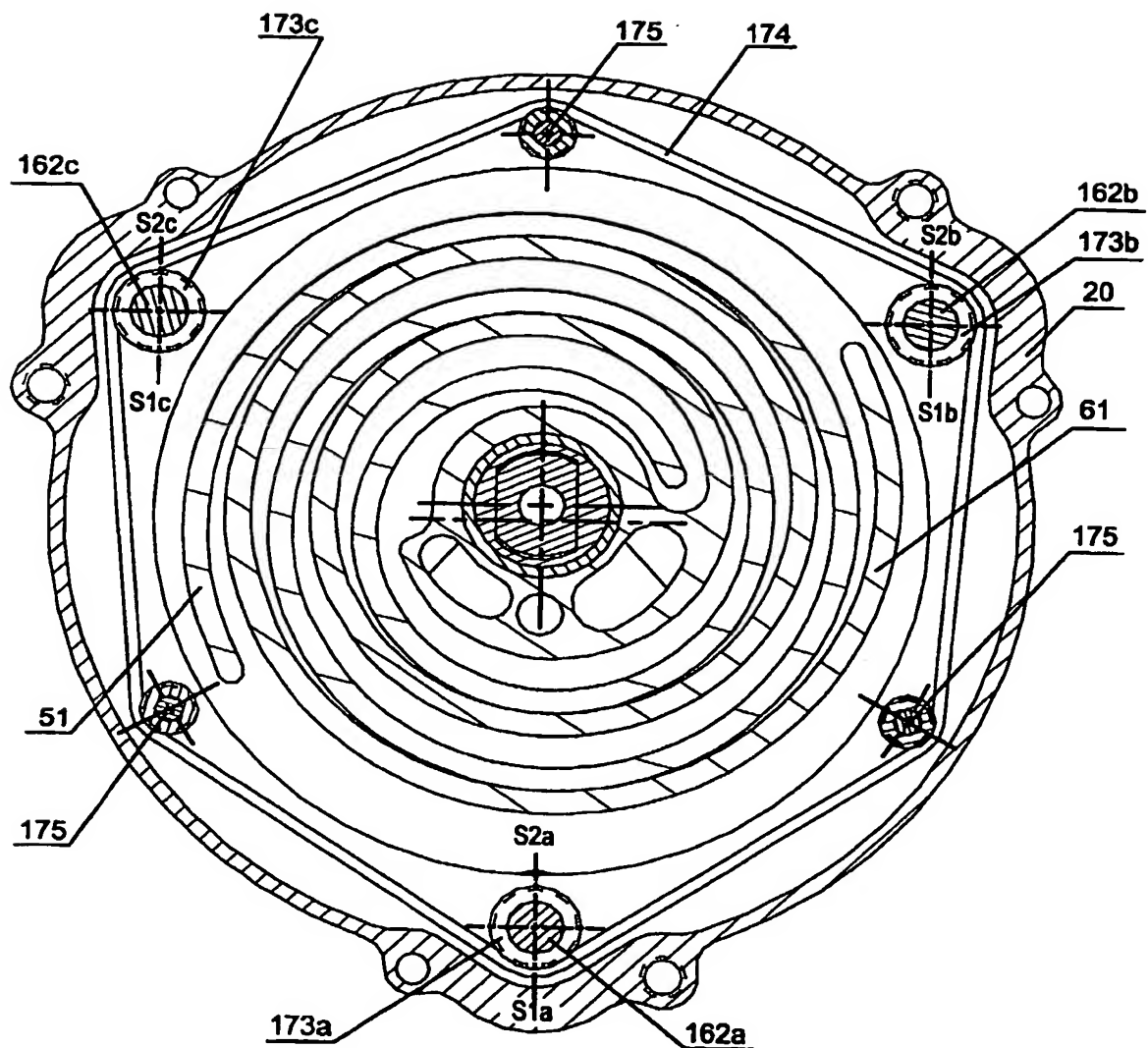
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FIG.9



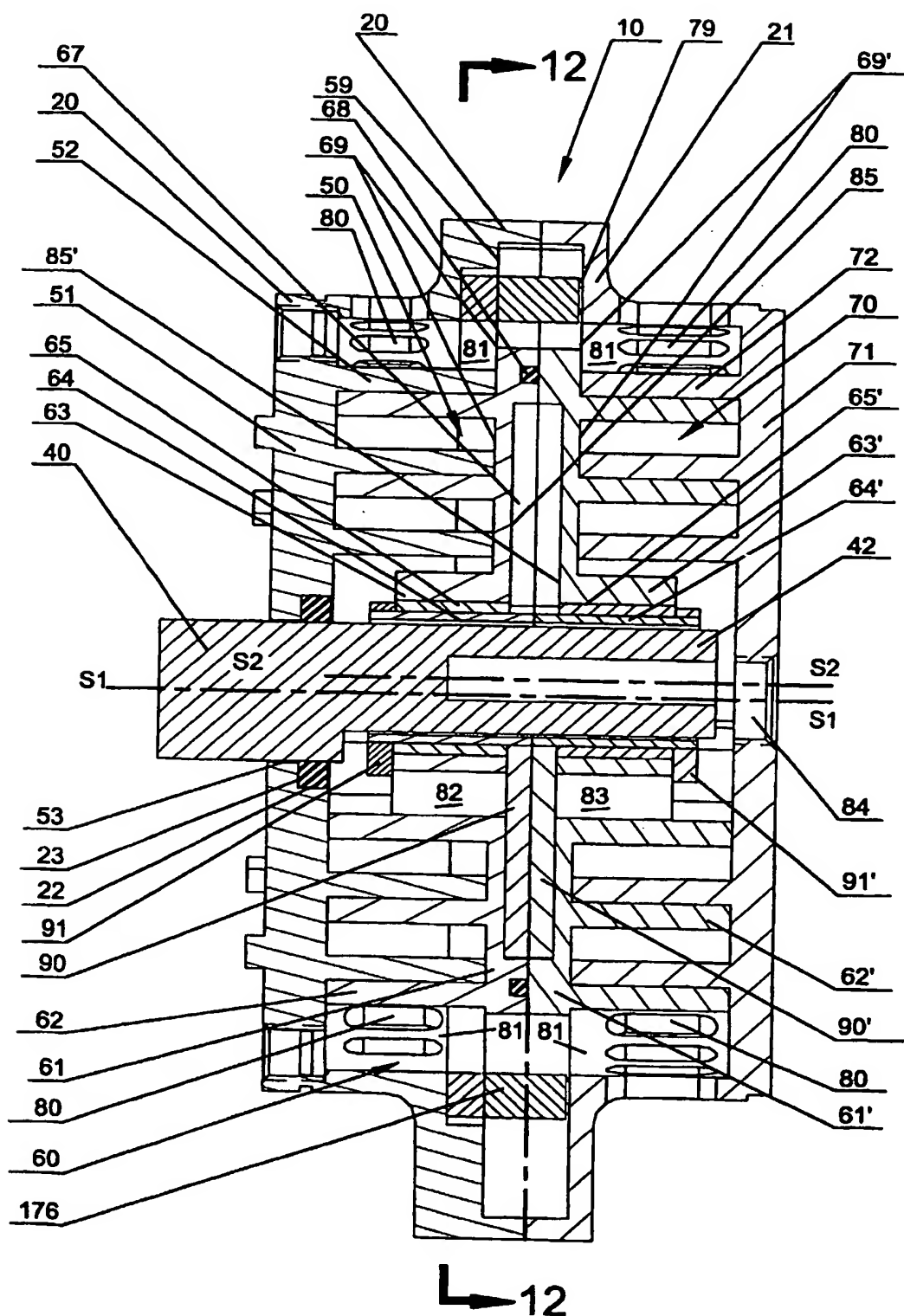
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FIG.10



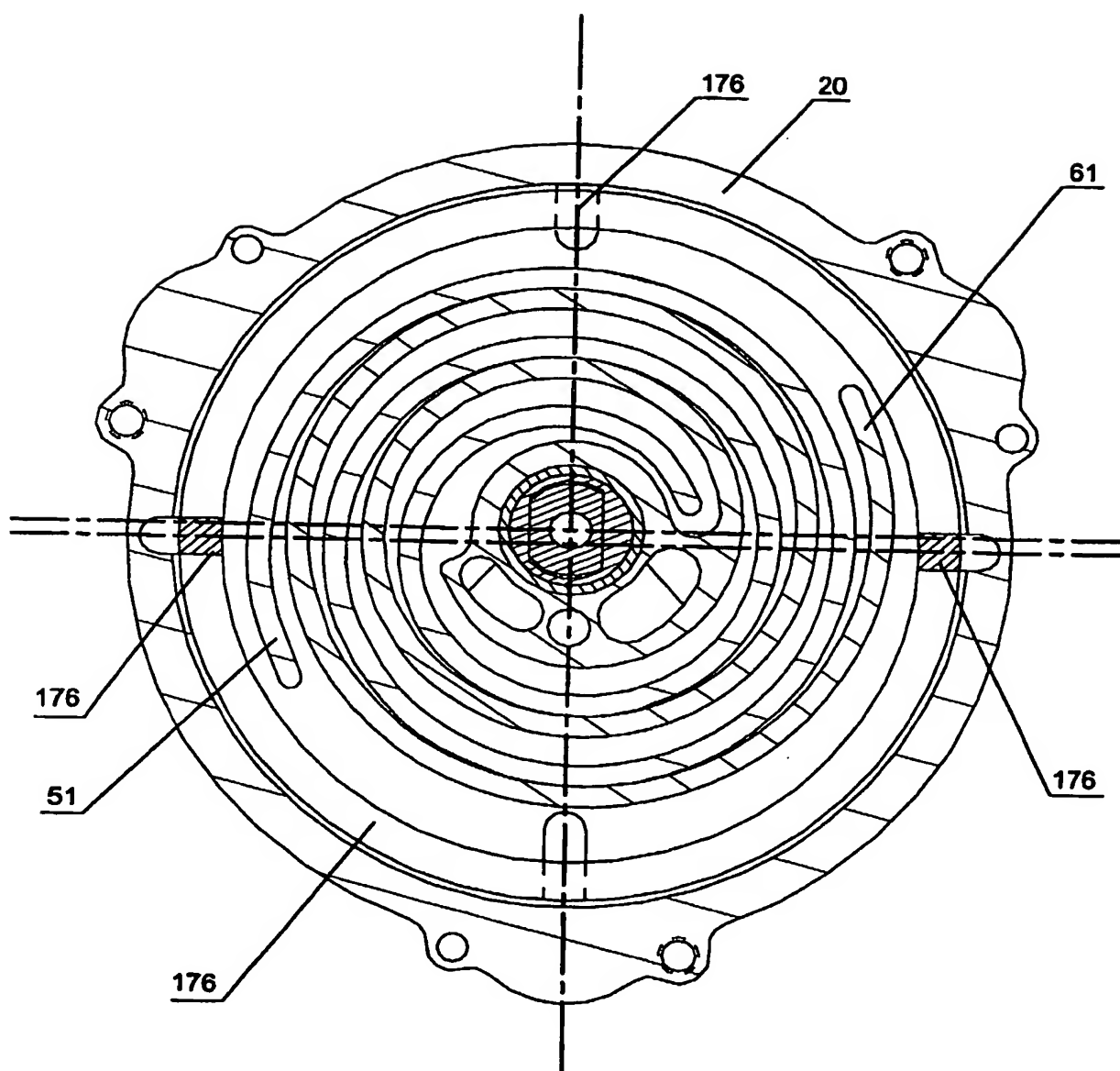
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FIG. 11



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FIG.12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/07100

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F01C 1/04

US CL : 418/55.2, 55.3, 55.5, 60, 151

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 418/55.2, 55.3, 55.5, 60, 151

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,304,047 A (SHIBAMOTO) 19 April 1994 (19.04.1994), column 6, lines 3-6 and column 8, lines 50-53.	31
A	US 4,990,071 A (SUGIMOTO) 05 February 1991 (05.02.1991)	1,8,16,24
A	US 6,290,477 B1 (GIGON) 18 September 2001 (18.09.1991)	1,8,16,24
A	US 5,197,868 A (CAILLAT et al) 30 March 1993 (30.03.1993)	4,12,20,27

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search

09 May 2003 (09.05.2003)

Date of mailing of the international search report

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